Week – 2 – March 13, 2013

Fundamentals of Satellite Remote Sensing

NASA ARSET- AQ
Introduction to Remote Sensing and Air Quality Applications
Winter 2014 Webinar Series

ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

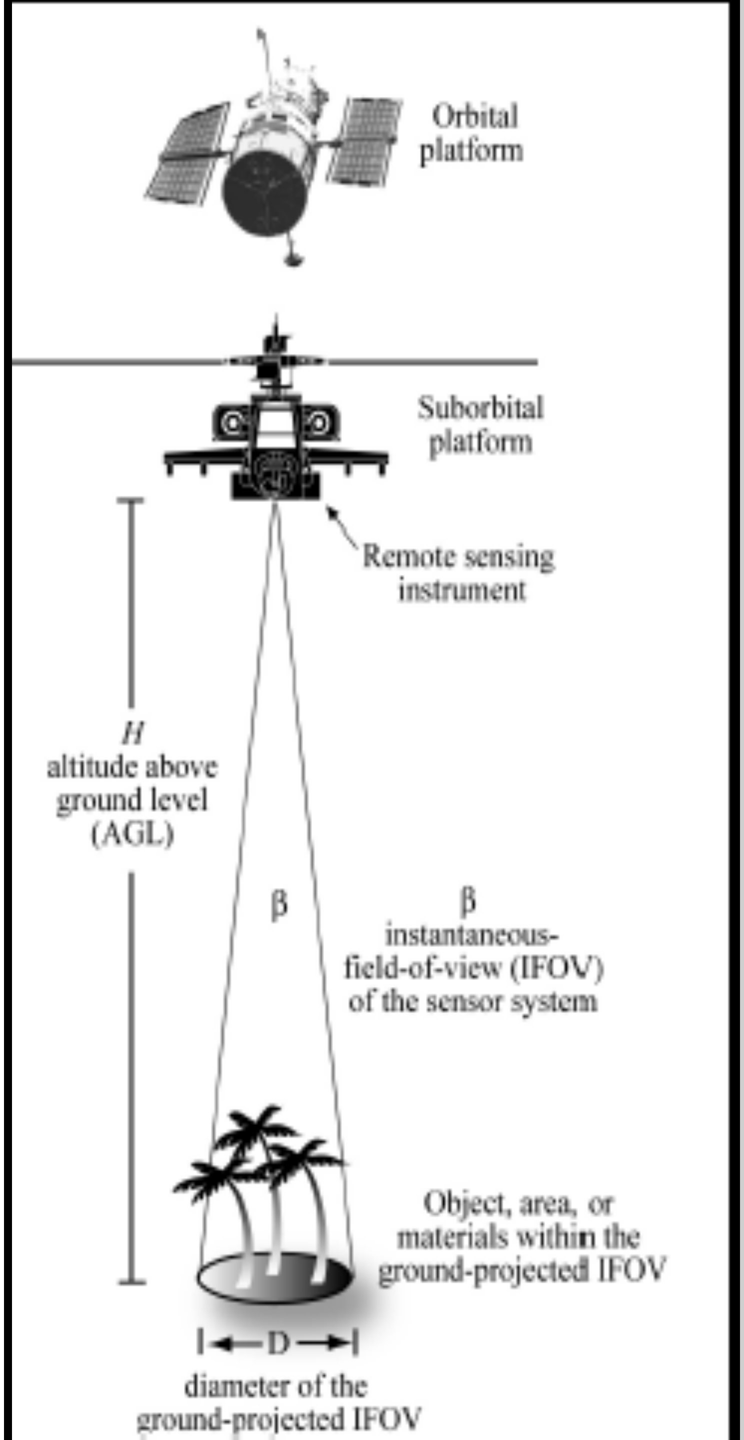
A project of NASA Applied Sciences

Outline

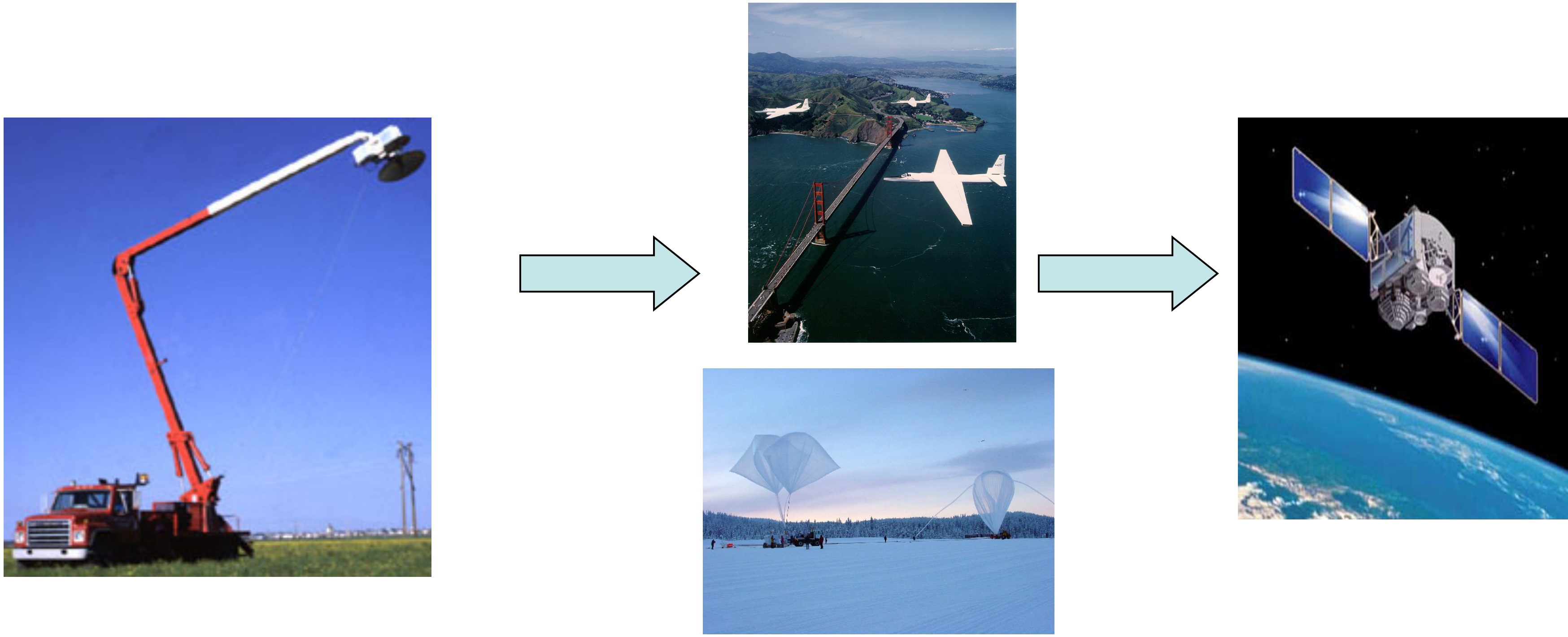
- Remote Sensing
- Active and Passive sensors
- Imagers, Sounders, and Radiometers
- Satellite Orbits
- Spatial, spectral, radiometric and temporal resolution

Remote Sensing …

Remote sensing instrument measures reflected or emitted radiation



Remote Sensing: examples



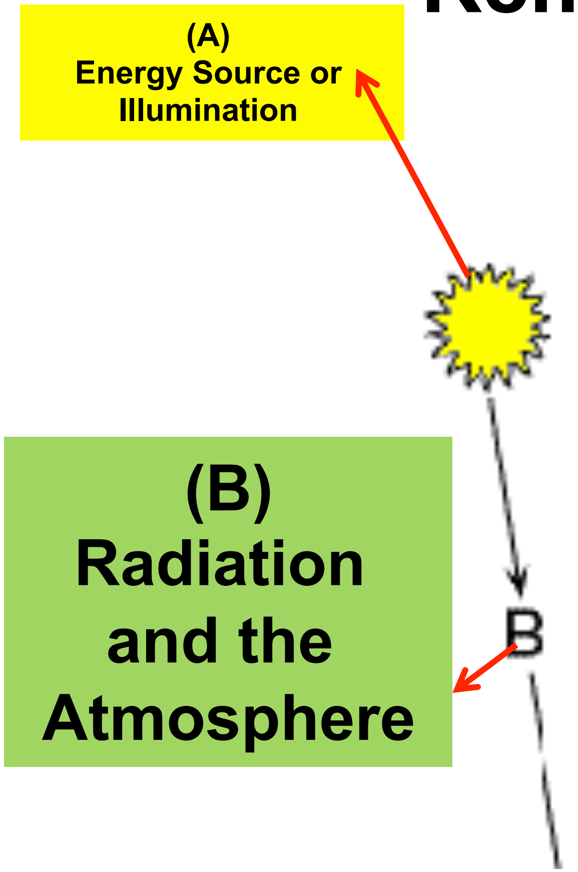
- Platform depends on application
    - What information do we want?
    - How much detail?
    - What type of detail?
    - How frequent?

Remote Sensing Process

(A)
Energy Source or Illumination

Reference: CCRS/CCT

Remote Sensing Process

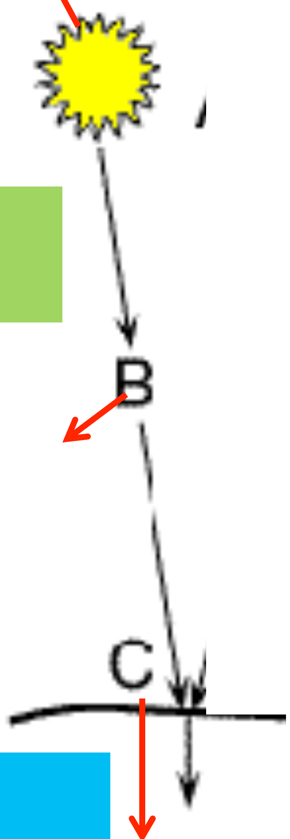


Reference:
CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination

(B)
Radiation and the Atmosphere

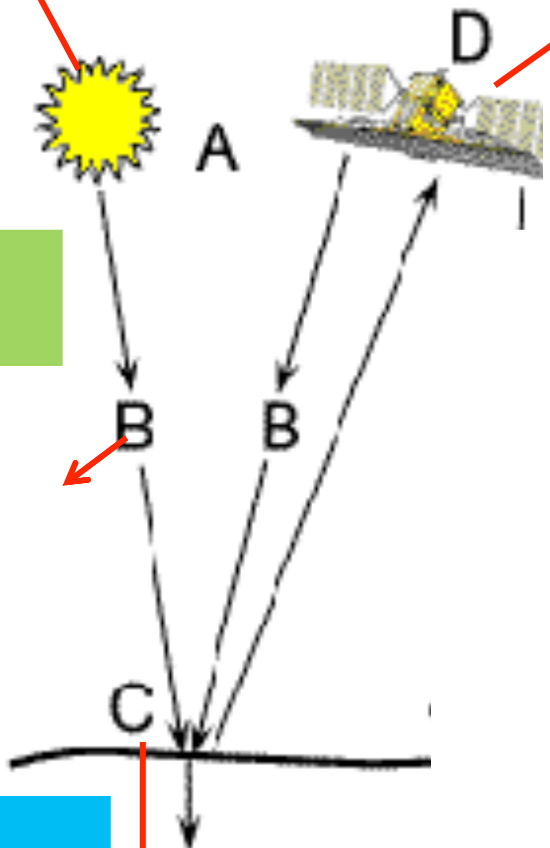


(C)
Interaction with the Target

Reference: CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination



(D)
Recording of Energy by the Sensor

(B)
Radiation and the Atmosphere

(C)
Interaction with the Target

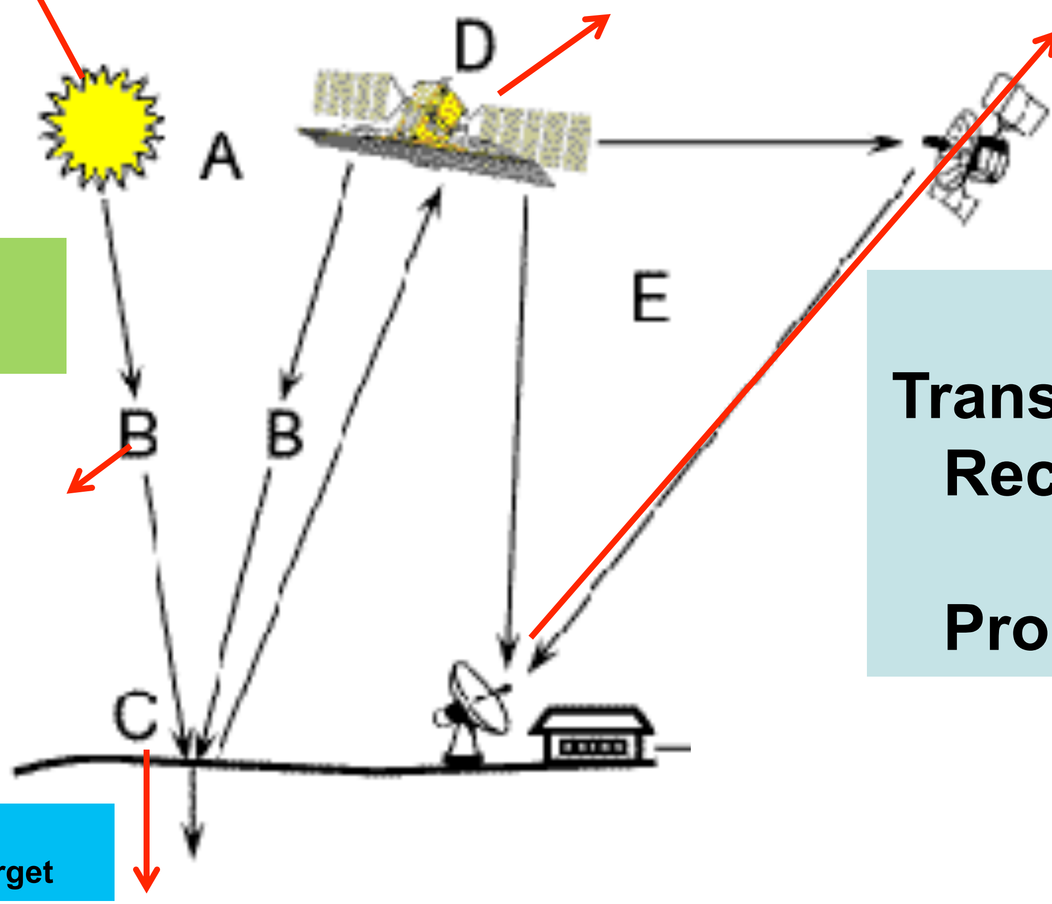
Reference: CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor

(B)
Radiation and the Atmosphere



(E)
Transmission, Reception, and Processing

(C)
Interaction with the Target

Reference: CCRS/CCT

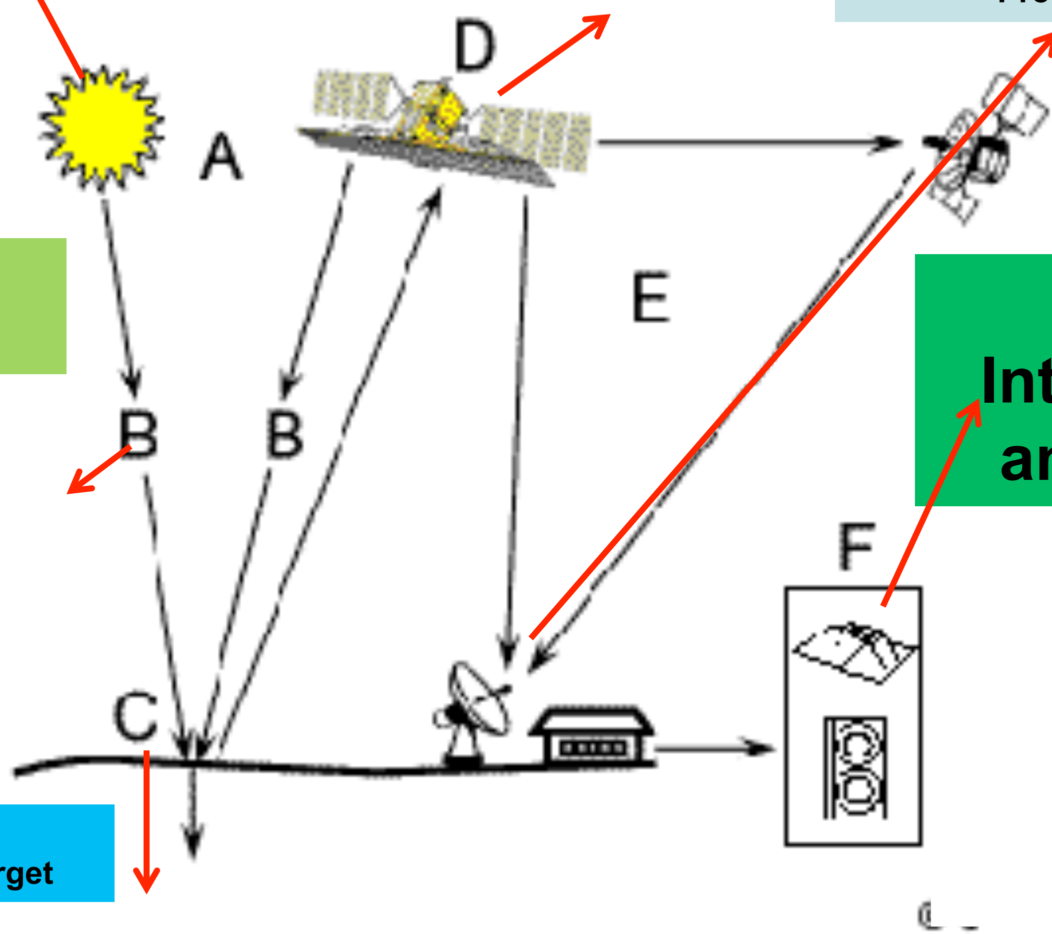
Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor

(E)
Transmission, Reception, and Processing

(B)
Radiation and the Atmosphere



(F)
Interpretation and Analysis

(C)
Interaction with the Target

Reference: CCRS/CCT

Remote Sensing Process

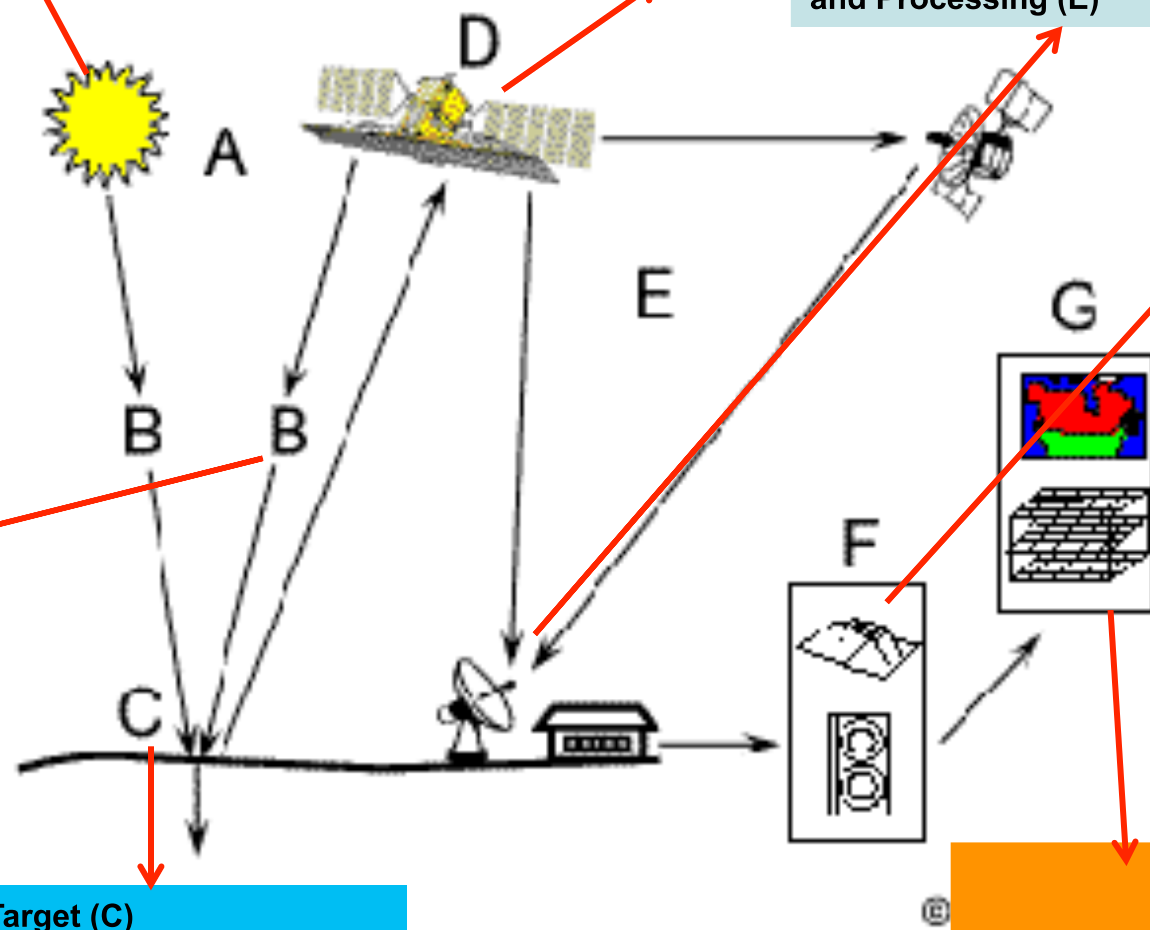
Energy Source or Illumination (A)

Recording of Energy by the Sensor (D)

Transmission, Reception, and Processing (E)

Radiation and the Atmosphere (B)

Interpretation and Analysis (F)



Interaction with the Target (C)

(G) Application

Reference: CCRS/CCT

Satellite/Sensor Classifications

Some of the ways satellites/sensor can be classified

- **Orbits**
  - Polar vs Geostationary
- **Energy source**
  - Passive vs Active …
- **Solar spectrum**
  - Visible, UV, IR, Microwave …
- **Measurement Technique**
  - Scanning, non-scanning, imager, sounders …
- **Resolution (spatial, temporal, spectral, radiometric)**
  - Low vs high (any of the kind)
- **Applications**
  - Weather, Ocean colors, Land mapping, Atmospheric Physics, Atmospheric Chemistry, Air quality, radiation budget, water cycle, coastal management …

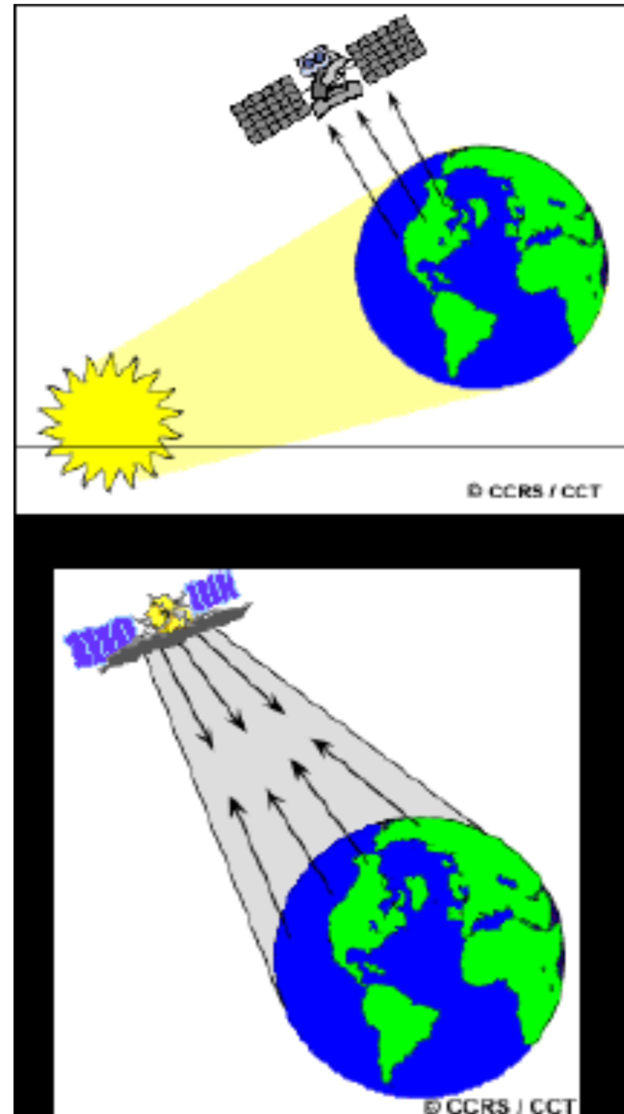
Remote Sensing …Sensors

Passive Sensors: Remote sensing systems which measure energy that is naturally available are called passive sensors.

Examples: ASTER, LANDSAT, AVHRR, TOMS, MODIS, MISR, OMI, CERES

Active Sensors: The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

Examples: LIDAR (CALIPSO, LITE), RADAR (SAR, PR, CPR), SONAR



Pause for Questions

- **Important Note:**

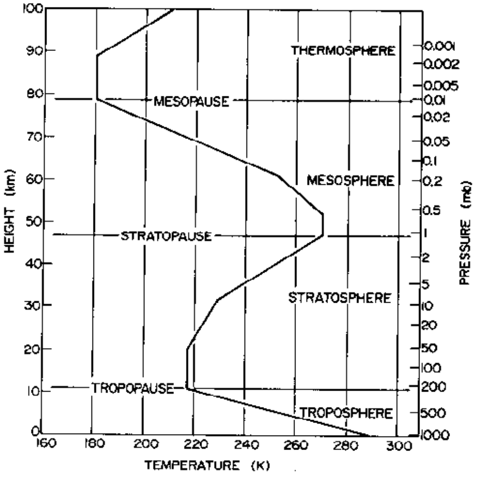
Passive instruments measure reflected/ emitted radiance at the top-of-atmosphere.

All other information is derived from this and some ancillary data.

Imagers & Sounders

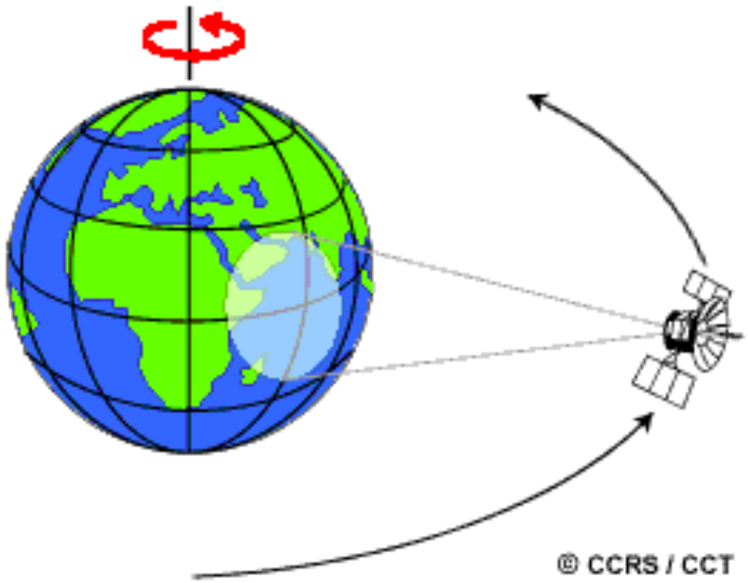
Imagers create images – MODIS, MISR

Active and passive sounders can provide vertical profiles –
Cloud Profiling Radar (CLOUDSAT)
SAR (Synthetic Aperture RADAR)
Atmospheric Infrared Sounder (AIRS)



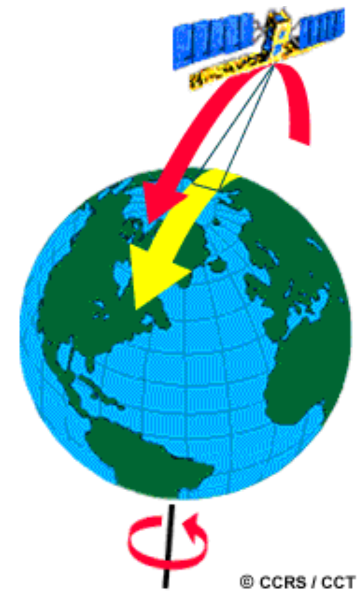
Common types of orbits

Geostationary

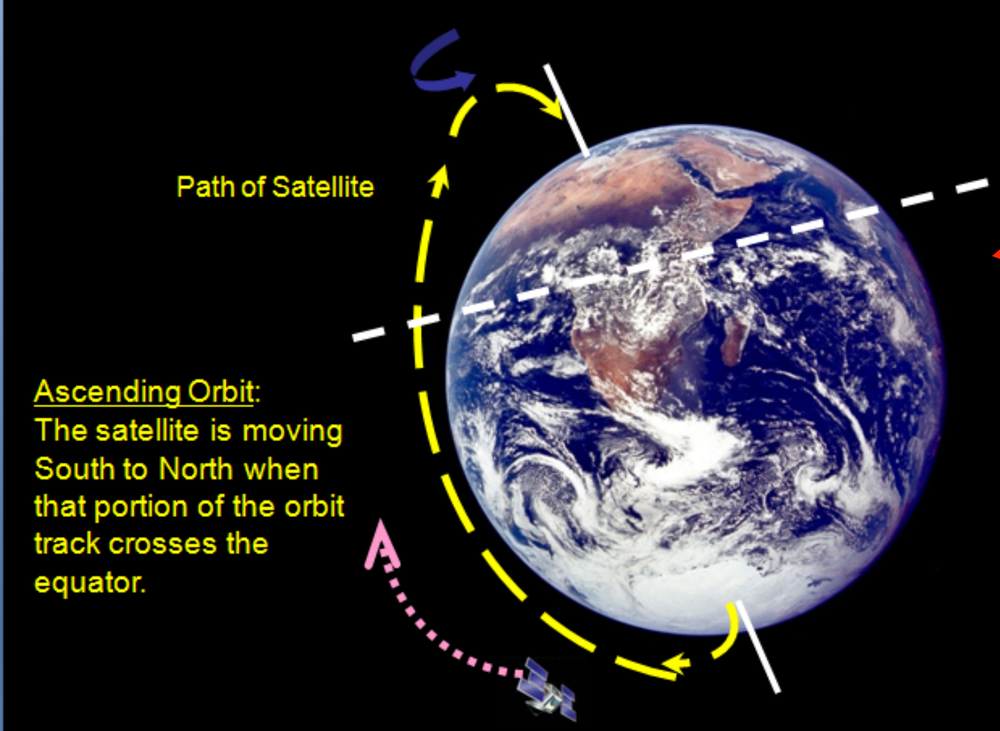


Geostationary orbit
An orbit that has the same Earth's rotational period
Appears 'fixed' above earth Satellite on equator at ~36,000km

Polar

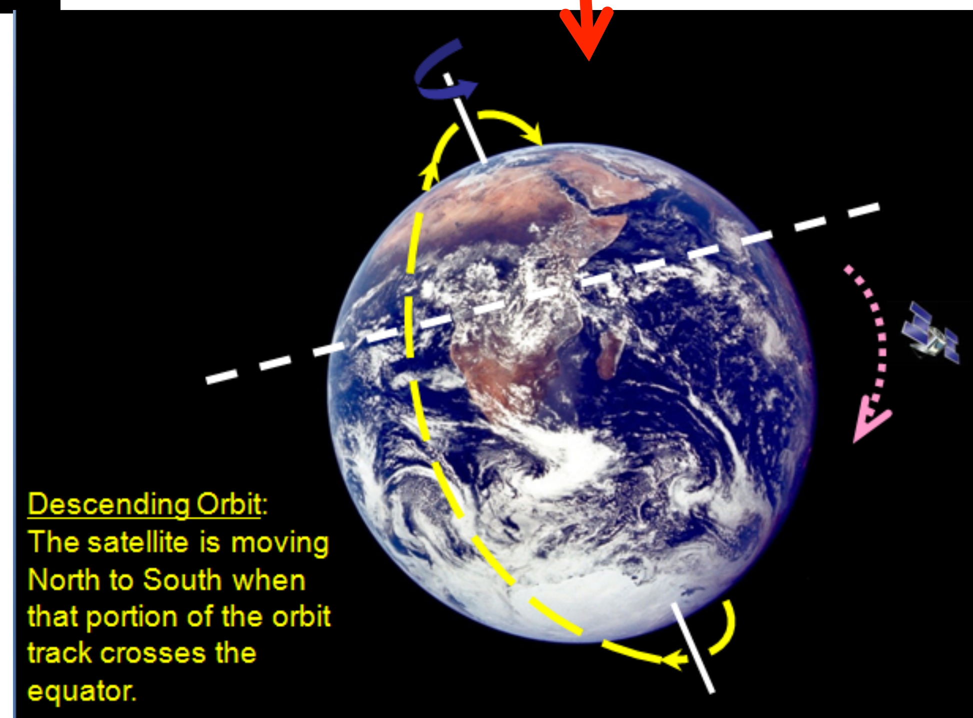


Polar orbiting orbit
fixed circular orbit above the earth, ~600-1000km in sun synchronous orbit with orbital pass at about same **local solar time** each day

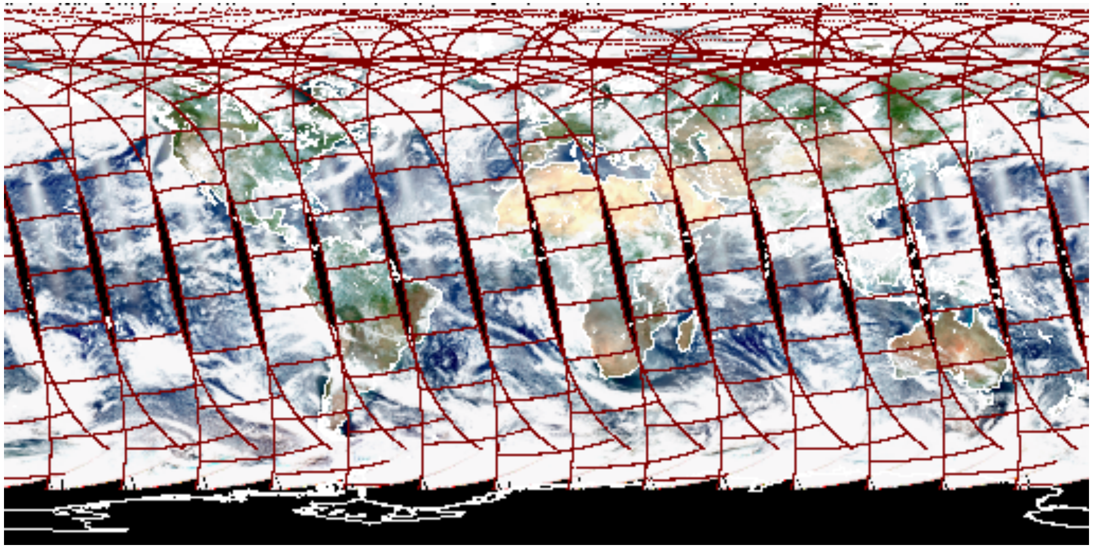


Ascending vs Descending

Polar Orbits



MODIS-Aqua ("ascending" orbit)



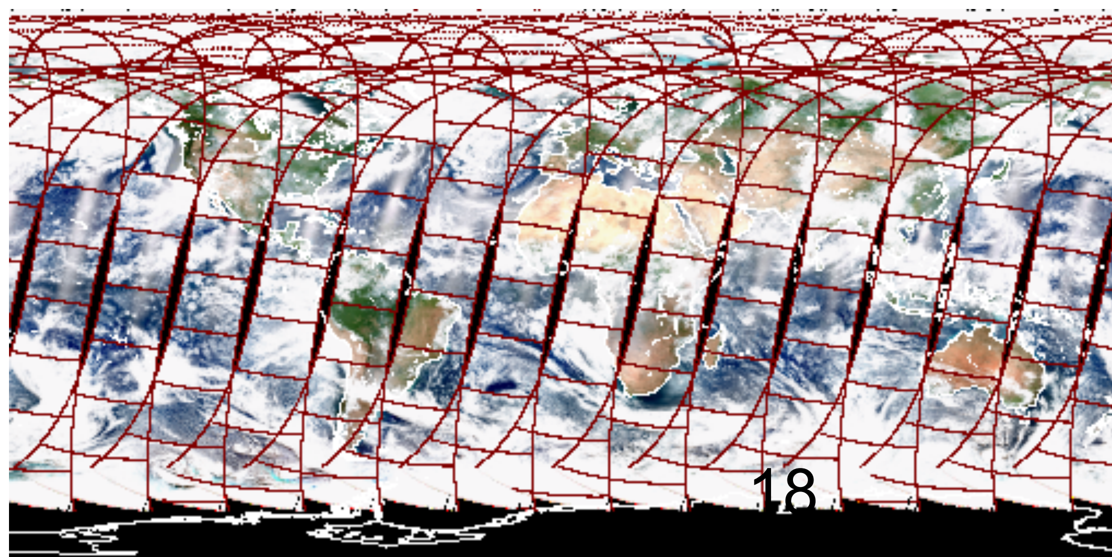
Approximately 1:30 PM local overpass time

Afternoon Satellite

MODIS-Terra ("descending")

Approximately 10:30 AM local overpass time

Morning Satellite



Remote Sensing – Resolutions

– **Spatial resolution**

The smallest spatial measurement.

– **Temporal resolution**

Frequency of measurement.

– **Spectral resolution**

The number of independent channels.

– **Radiometric resolution**

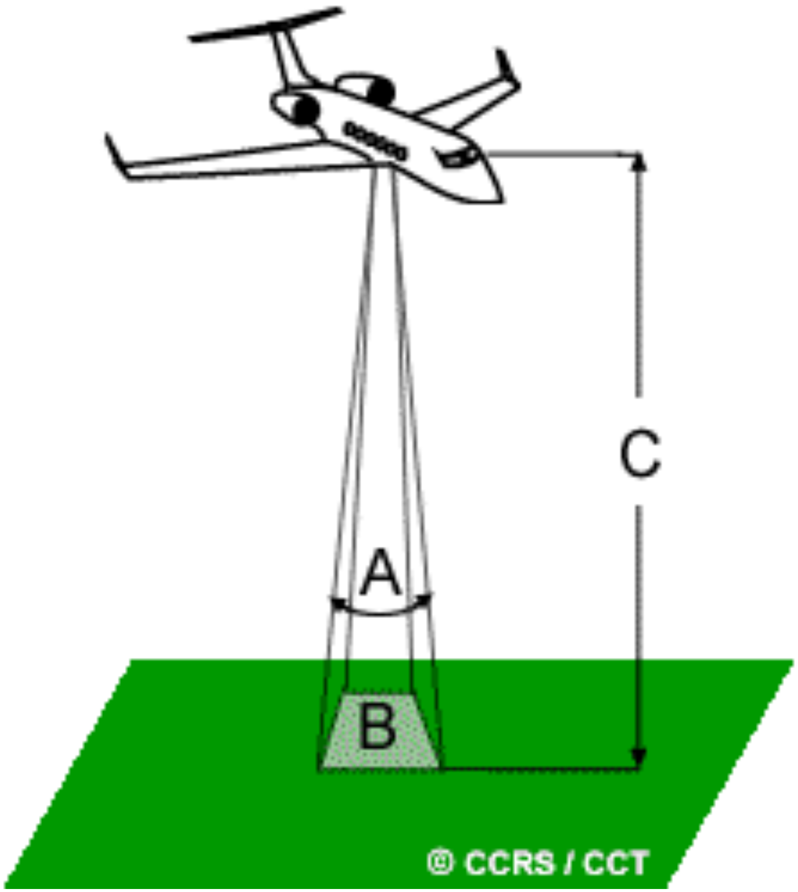
The sensitivity of the detectors.

Pixel

pixels - the **smallest units of an image**.

Image pixels are normally square (but not necessary) and represent a certain area on an image/Earth.

Instantaneous Field of View (IFOV)

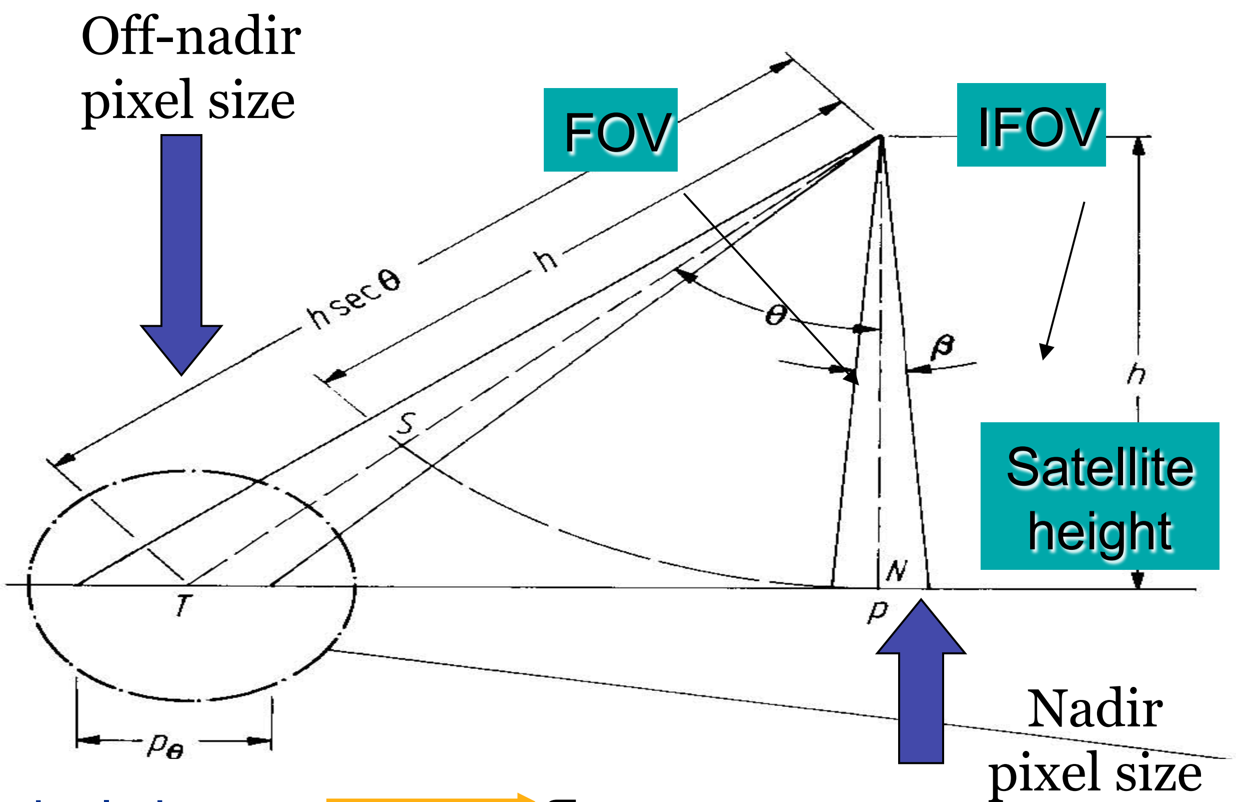


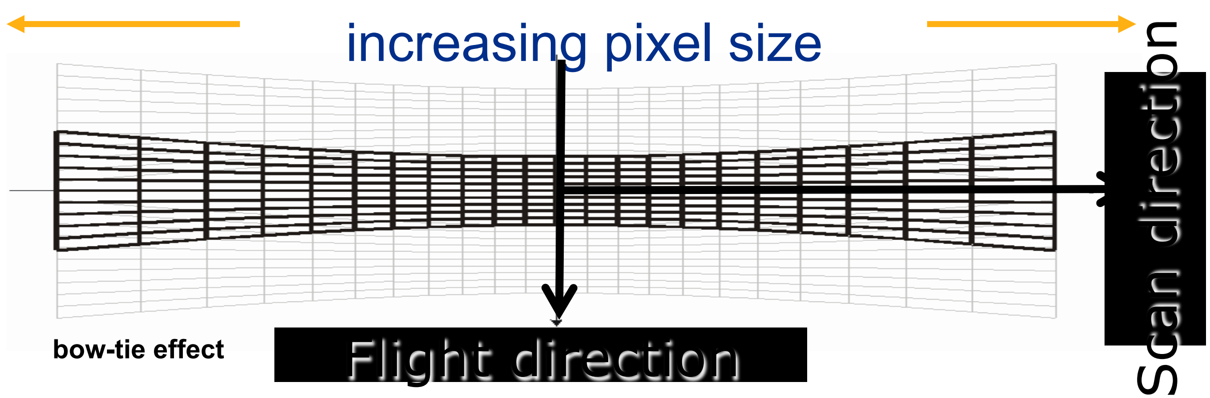
The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B). The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the **resolution cell** and determines a sensor's maximum spatial resolution

Spatial Resolution

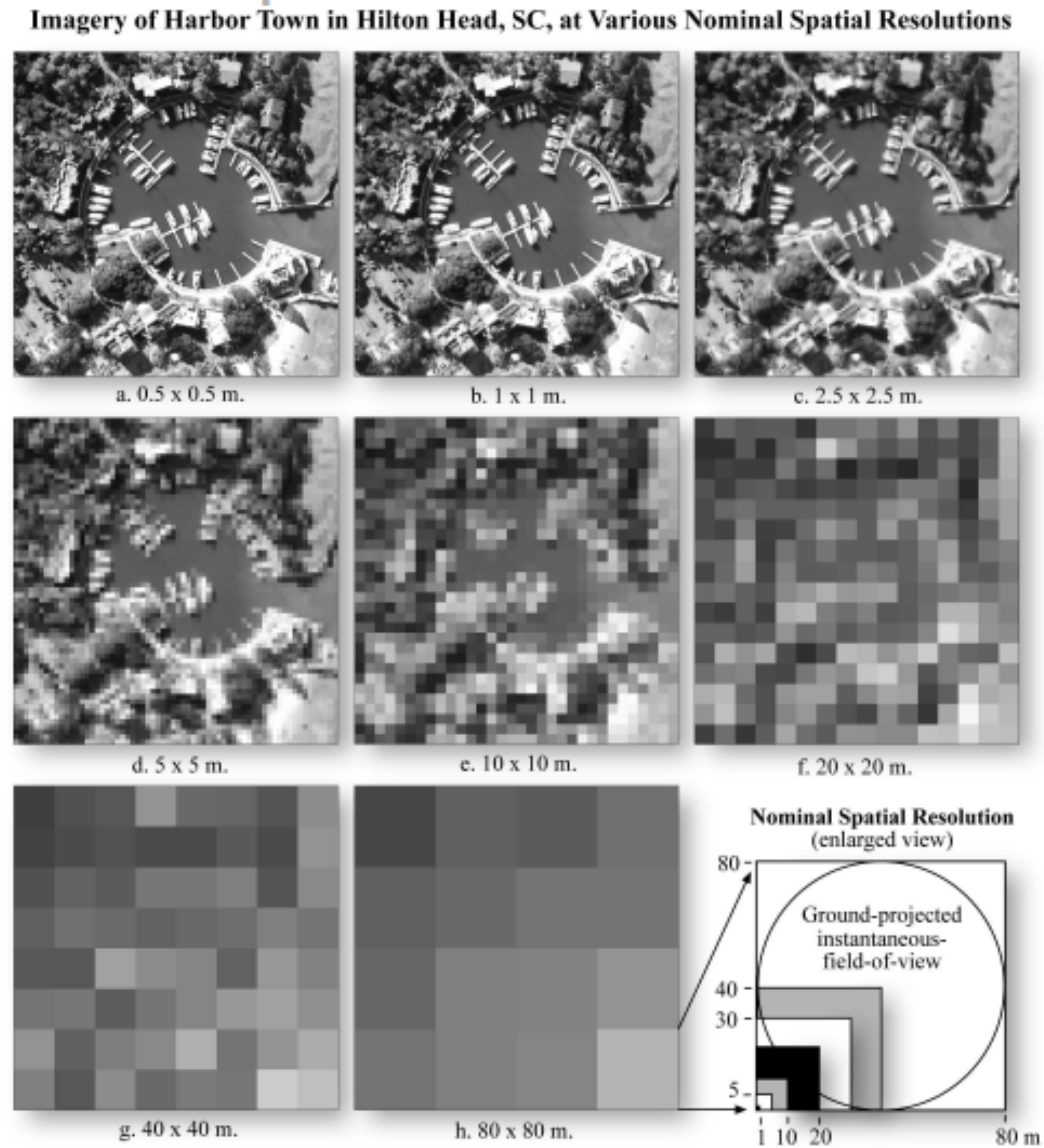
- Spatial Resolution : The highest magnification of the sensor at the ground surface

- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.

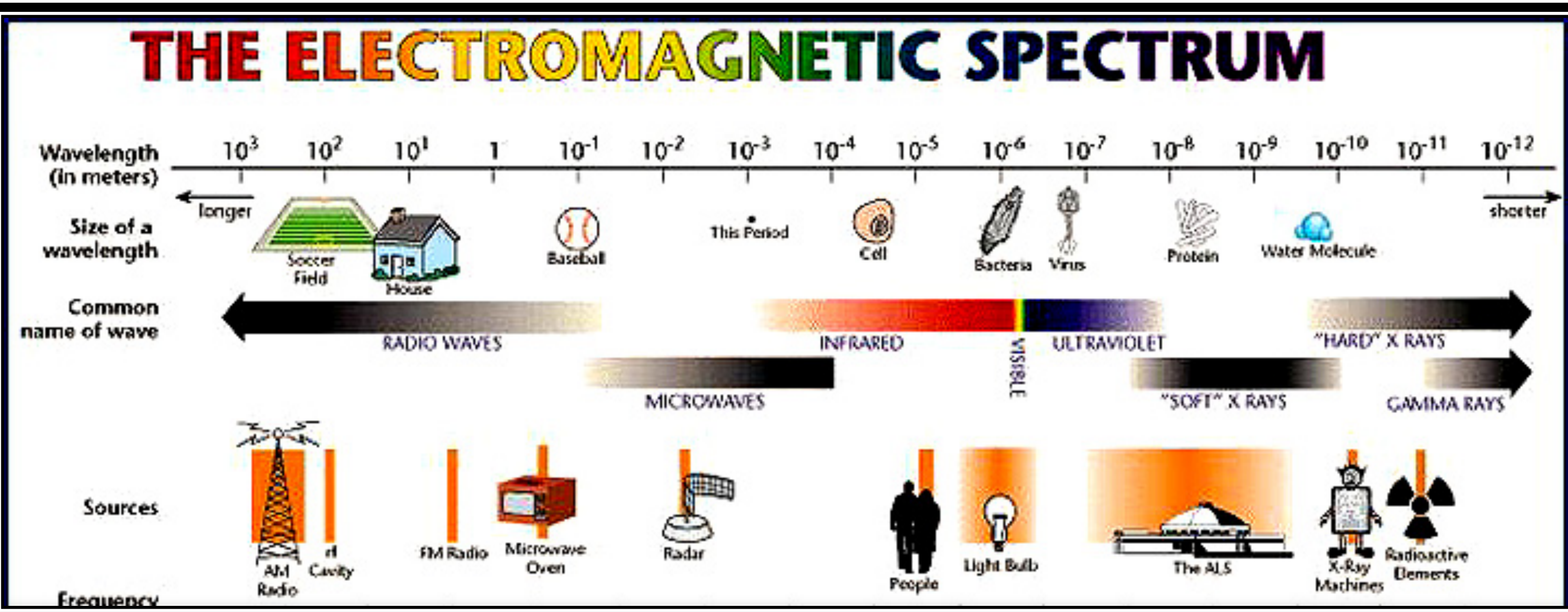




Why is spatial resolution important ?

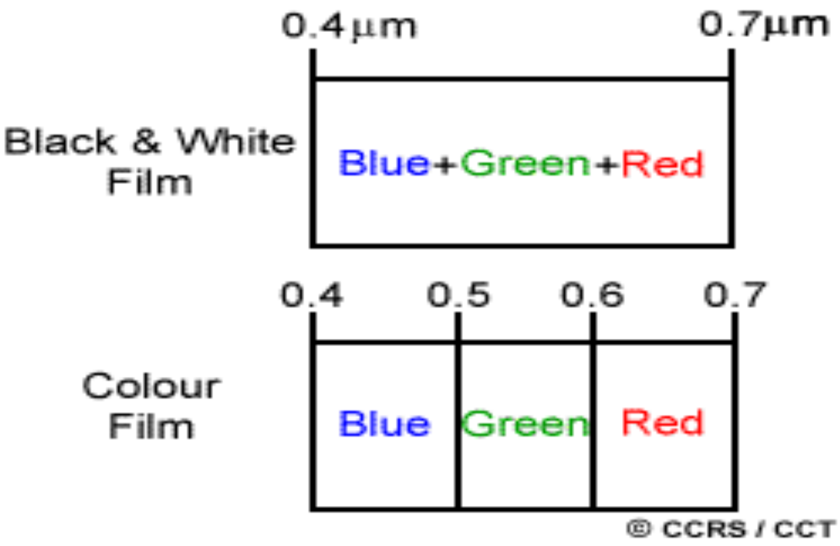


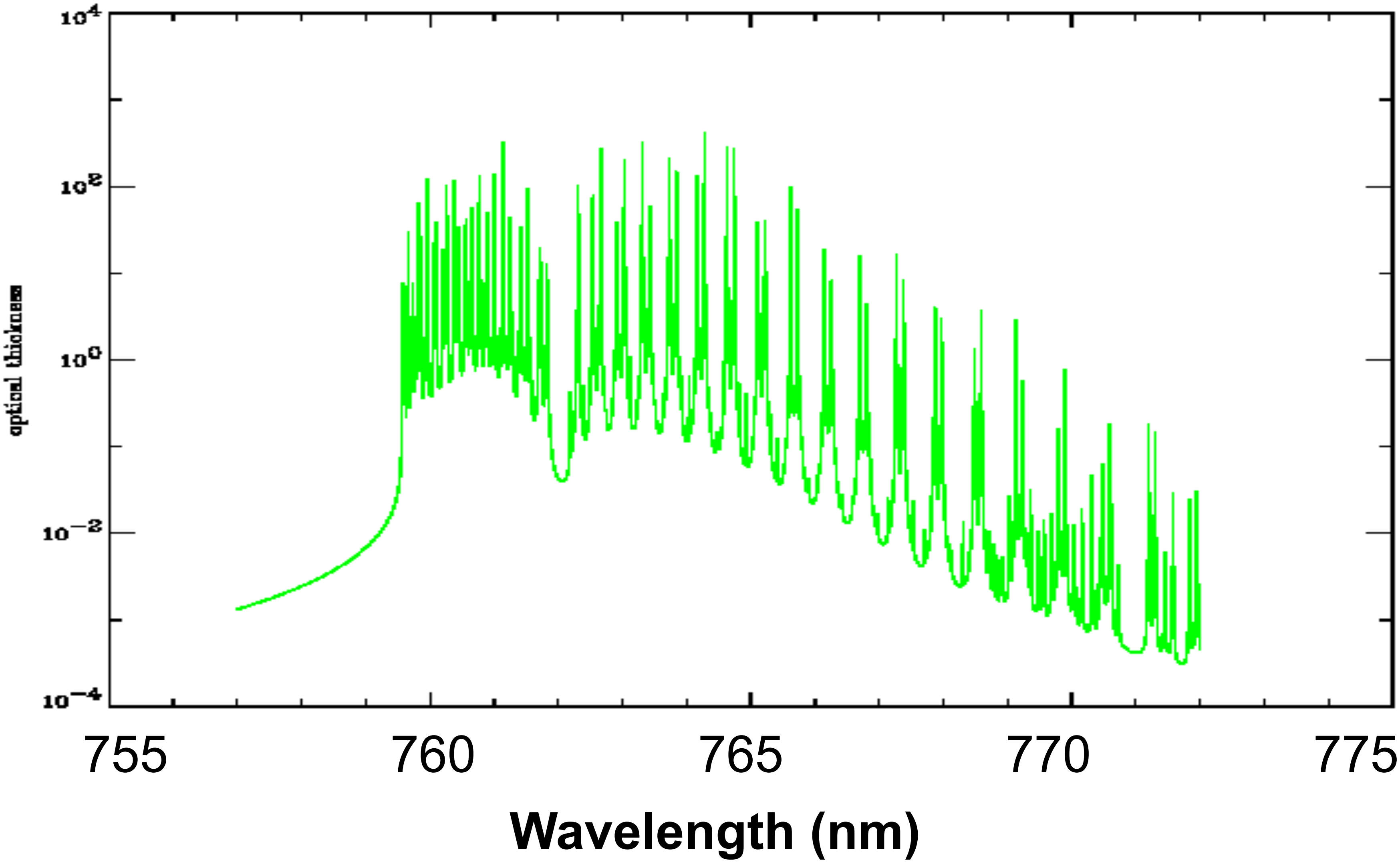
Spectral Resolution -



Spectral Resolution

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.
- **multi-spectral sensors - MODIS**
- **hyper spectral sensors - OMI, AIRS**





In order to capture information contained in a narrow spectral region – hyper spectral instruments such as OMI, or AIRS are required

Radiometric Resolution

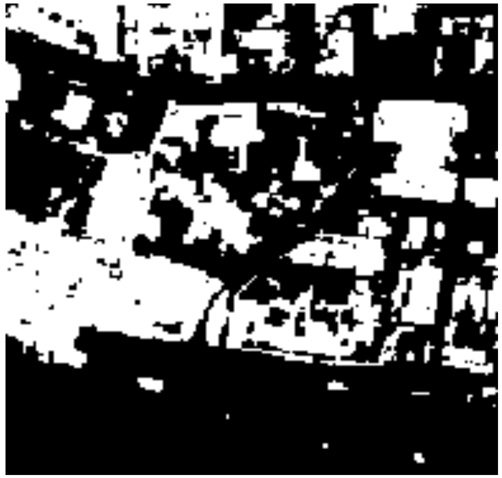
•Imagery data are represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2.

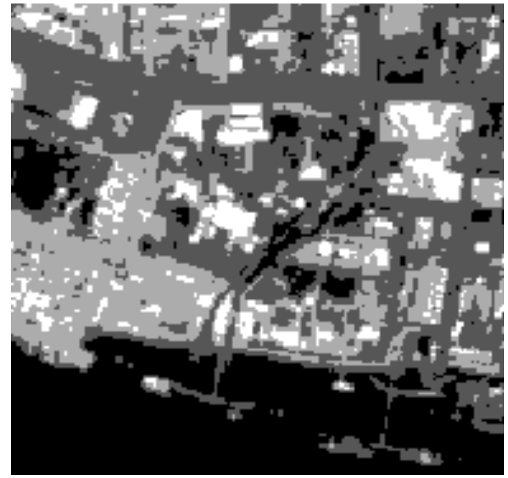
•The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded.

- **12 bit sensor (MODIS, MISR) – 2^{12} or 4096 levels**
- **10 bit sensor (AVHRR) – 2^{10} or 1024 levels**
- **8 bit sensor (Landsat TM) – 2^{8} or 256 levels (0-255)**
- **6 bit sensor (Landsat MSS) – 2^{6} or 64 levels (0-63)**

Radiometric Resolution

2 - levels





4 - levels

8 - levels

16 - levels

In classifying a scene, different classes are more precisely identified if radiometric precision is high.

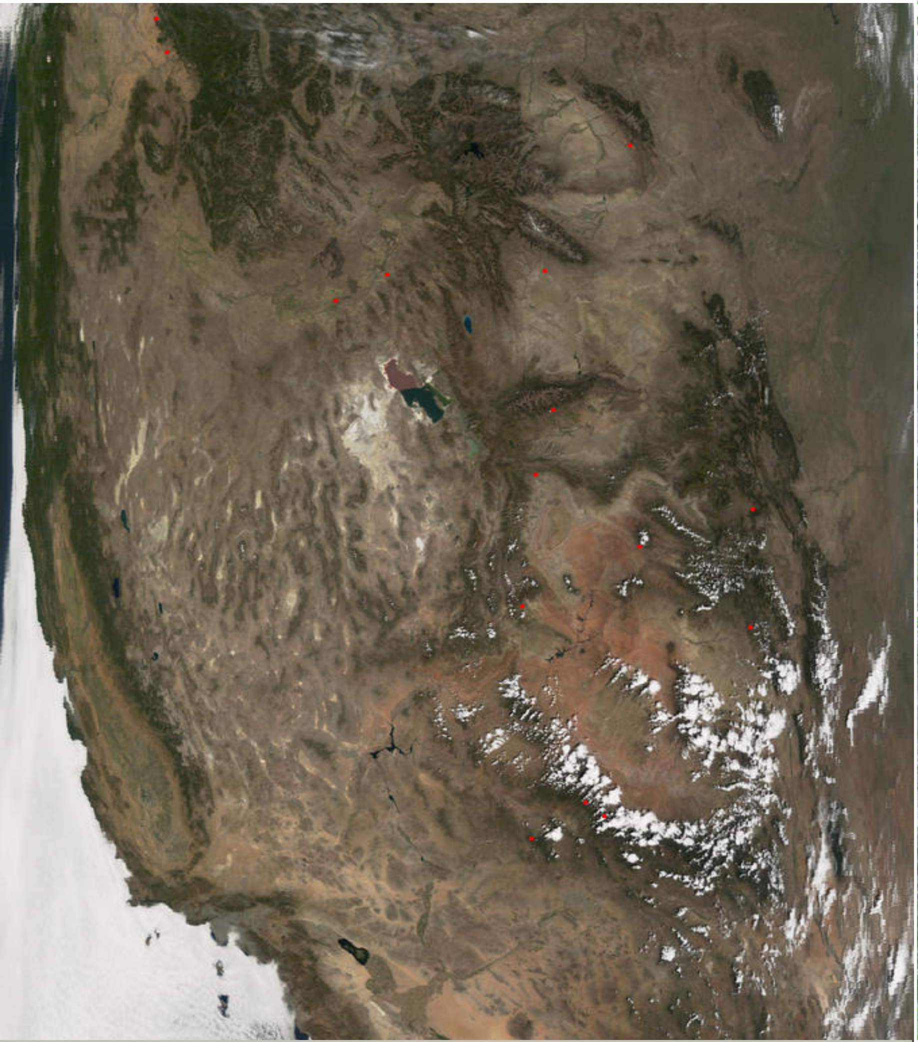
Temporal Resolution

- How frequently a satellite can provide observation of same area on the earth
- It mostly depends on swath width of the satellite – larger the swath – higher the temporal resolution

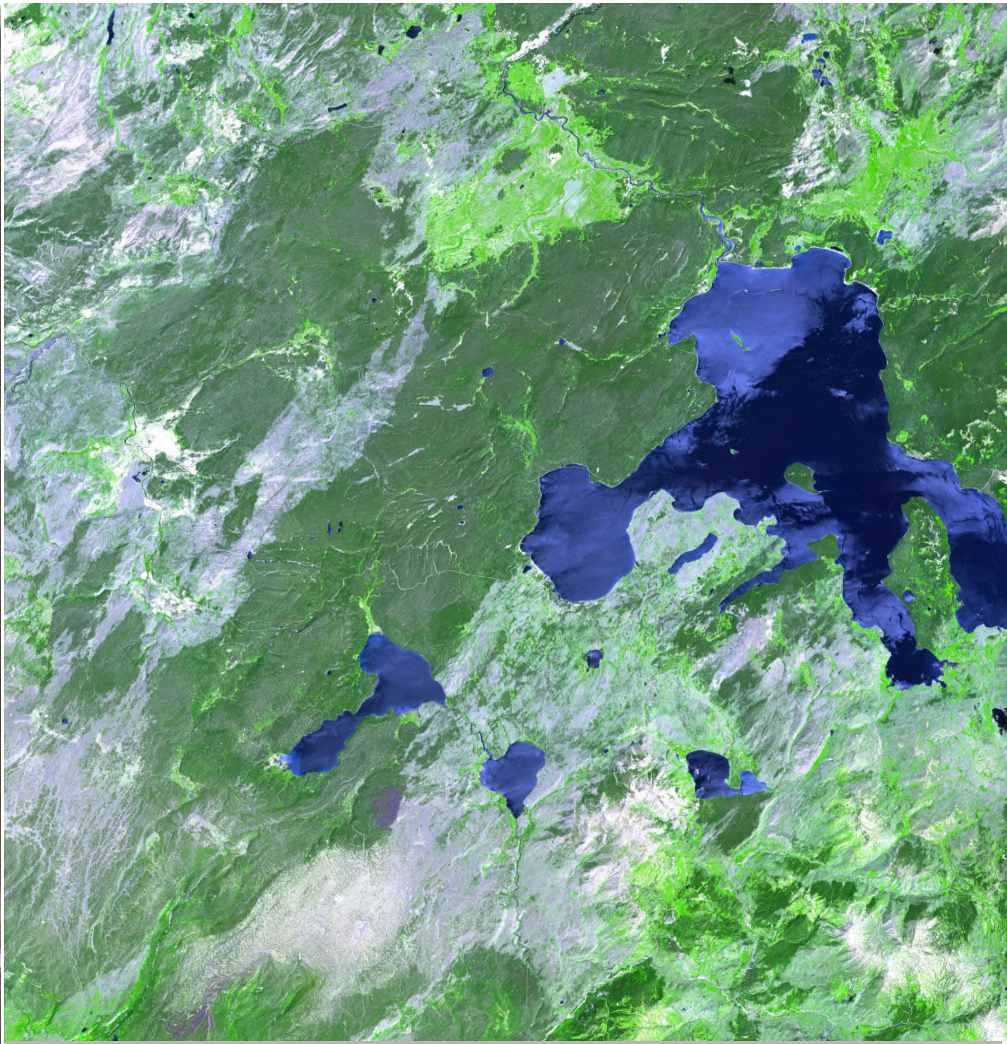
- **MODIS – 1-2 days – 16 day repeat cycle**
- **OMI – 1-2 days**
- **MISR – 6-8 days**
- **Geostationary – 15 min to 1 hour**

  (but limited to one specific area of the globe)

Remote Sensing – Trade offs

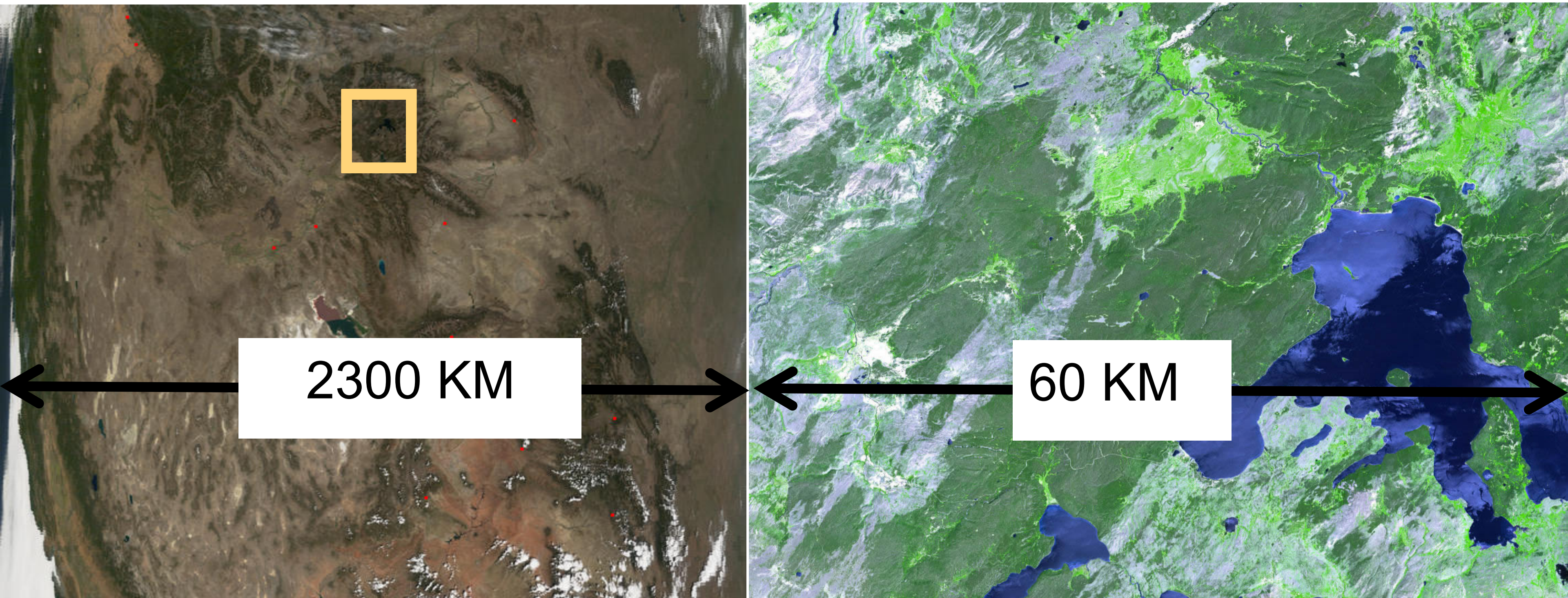


MODIS 500 Meter
True color image



Aster Image
15 M Resolution

Remote Sensing – Trade offs



•The different resolutions are the limiting factor for the utilization of the remote sensing data for different applications. Trade off is because of technical constraints.

•Larger swath is associated with low spatial resolution and vice versa

•Therefore, often satellites designs are applications oriented

Trade Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolutions at the same time
- MODIS, OMI and several other sensors can obtain global coverage every one – two days because of their wide swath width
- Higher resolution polar orbiting satellites may take 8 – 16 days for global coverage or may never provide full coverage of the globe.
- Geostationary satellites obtain much more frequent observations but at lower resolution due to the much greater orbital distance.

Instrument Capabilities – for Air Quality

Imagers 

MODIS – Terra and Aqua
250m-1 KM Resolution

MISR
275m- 1.1 KM Resolution

Polder
6 KM Resolution

Radiometers 

OMI –
13 x 24 KM Resolution

GOME-2
40 x 80 KM Resolution

SCIAMACHY
30 x 60 KM Resolution

Three Satellites for air quality data

- **MODIS (Terra and Aqua)**
  - 36 spectral channels
  - columnar aerosol loading – can be used to get particulate matter mass concentration
- **MISR (Terra)**
  - 4 spectral bands and 9 angular bands
  - Columnar aerosol loading in different particle size bins in some cases aerosol heights
- **OMI (Aura)**
  - Absorbing aerosols
  - Trace gases

Geophysical Products

Images

Cloud Fraction

Aerosol Optical Depth – Particulate Matter

Total Column Trace Gas Amount

Trace Gas Layer Concentrations

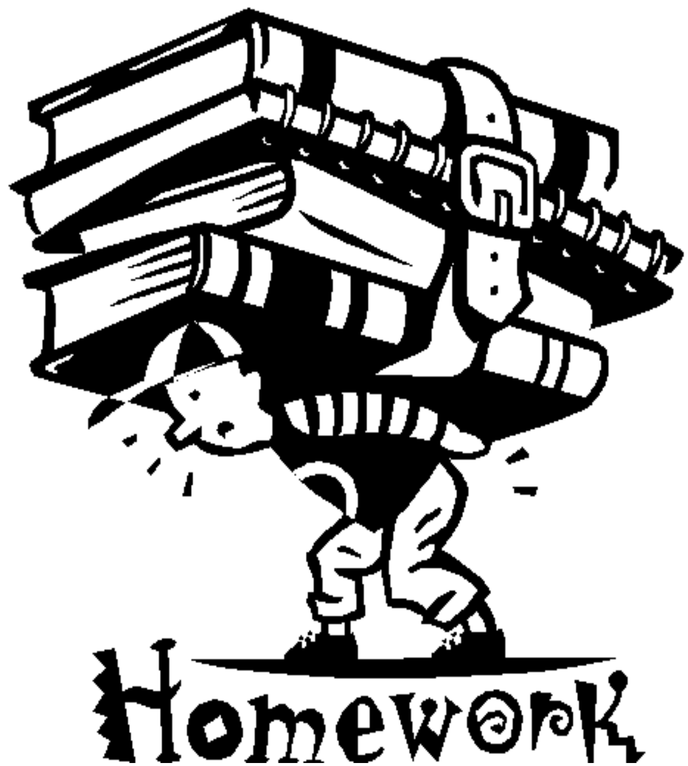
Land Cover Type

Vegetation Index

Factors which change with each instrument

- Calibration accuracy
- Quality Assurance
- Data formats
- Product Resolutions
- Level of data products
- Current release of the data and data history

Assignment



Assignment #2 Due Wednesday January 15th